CERTIFICATION

I, Yoshihiko Takeda, 10-1 Higashikotari 1-chome, Nagaokakyo-shi, Kyoto-fu, Japan 617-8555, do hereby certify that I am conversant in the English language and the Japanese language, and I further certify that, to the best of my knowledge and belief, the attached English translation is a true and correct translation of Japanese Patent Application No. 2003-046269 filed on February 24, 2003.

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[Title of the Invention] SURFACE ACOUSTIC WAVE FILTER AND COMMUNICATION APPARATUS

[Claims]

[Claim 1] A surface acoustic wave filter comprising at least:

a piezoelectric substrate;

an insulating pattern disposed on the piezoelectric substrate and having permittivity lower than that of the piezoelectric substrate; and

a conductor pattern disposed on at least one of the piezoelectric substrate and the insulating pattern,

wherein part of the conductor pattern serves as IDTs and another part thereof serves as wiring traces, and

at a portion where wiring traces having different potentials face each other in a plan view, at least part of at least one of the wiring traces is disposed on the insulating pattern.

[Claim 2] A surface acoustic wave filter according to Claim 1, wherein the conductor pattern comprises a first conductor pattern disposed on the piezoelectric substrate, part thereof serving as the IDTs; and a second conductor pattern which is in conduction with the first conductor pattern, part thereof being disposed on the insulating pattern.

[Claim 3] A surface acoustic wave filter comprising:

a piezoelectric substrate;

a first conductor pattern disposed on the piezoelectric substrate, part thereof serving as IDTs and at least another part thereof serving as a first wiring pattern;

an insulating pattern disposed on the piezoelectric substrate and on the first wiring pattern; and

a second conductor pattern disposed on the piezoelectric substrate and on the insulating pattern and being in conduction with the first conductor pattern, at least part thereof serving as a second wiring pattern,

wherein, at a portion where wiring traces having different potentials face each other in a plan view in the first and second wiring patterns, at least part of at least one of the wiring traces is disposed on the insulating pattern, and

the first wiring pattern is crossed with the second wiring pattern in at least one point, with the insulating pattern disposed therebetween.

[Claim 4] A surface acoustic wave filter according to any one of Claims 1 to 3, wherein one of the wiring traces having different potentials receives an input signal and the other wiring trace receives an output signal.

[Claim 5] A surface acoustic wave filter according to any one of Claims 1 to 4, wherein the relative permittivity of

the insulating pattern is less than 4.

[Claim 6] A surface acoustic wave filter according to any one of Claims 1 to 5, wherein the insulating pattern comprises resin.

[Claim 7] A surface acoustic wave filter according to any one of Claims 1 to 6, wherein the insulating pattern has a thickness of 0.5 μm or more.

[Claim 8] A surface acoustic wave filter according to any one of Claims 1 to 7, wherein the relative permittivity of the piezoelectric substrate is 20 or more.

[Claim 9] A surface acoustic wave filter according to Claim 8, wherein the piezoelectric substrate comprises any of $LiTaO_3$, $LiNbO_3$, and $Li_2B_4O_7$.

[Claim 10] A surface acoustic wave filter according to any one of Claims 1 to 9, wherein the center frequency of a pass band is 500 MHz or more.

[Claim 11] A surface acoustic wave filter according to any one of Claims 1 to 9, wherein the center frequency of a pass band is 1 GHz or more.

[Claim 12] A surface acoustic wave filter according to any one of Claims 1 to 11, wherein the surface acoustic wave filter has a balance-to-unbalance transformer function and includes a balanced signal terminal and an unbalanced signal terminal.

[Claim 13] A surface acoustic wave filter according to

Claim 12, wherein at least one of a wiring trace connected to the balanced signal terminal and a wiring trace connected to the unbalanced signal terminal is disposed on the insulating pattern.

[Claim 14] A communication apparatus comprising the surface acoustic wave filter according to any one of Claims 1 to 13.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to surface acoustic wave (SAW) filters of an improved transmission characteristic suitable for band-pass filters of communication apparatuses, such as portable phones, and to communication apparatuses including the same.

[0002]

[Description of the Related Art]

In compact communication apparatuses such as portable phones, band-pass filters having a pass-band of several tens of MHz to several GHz have been commonly used. As an example of the band-pass filters, compact SAW filters can be used.

[0003]

As shown in Fig. 15, a SAW filter 500 includes a filter element 504 having a reflector 510, interdigital transducers

(IDTs) 501 to 503, and a reflector 511, which are arranged along a SAW-propagating direction on a piezoelectric substrate 100. Herein, each of the IDTs 501 to 503 functions as an electric signal to SAW coupling transducer including a pair of comb electrodes engaged with each other.

[0004]

An input pad 520, an output pad 521, and ground pads 522 to 524 are disposed on the piezoelectric substrate 100, and wiring traces 525 to 530 for electrically connecting the IDTs 501 to 503 and the pads 520 to 524 are also disposed on the piezoelectric substrate 100.

[0005]

Herein, all of the IDTs 501 to 503, the reflectors 510 and 511, the pads 520 to 524, and the wiring traces 525 to 530 are part of a conductive thin-film pattern on the piezoelectric substrate 100.

[0006]

When an electric signal is applied to the input pad 520 of the SAW filter 500, SAW is excited by the IDTs 501 and 503, and a standing wave of the SAW is generated in a region including the IDTs 501 to 503 sandwiched by the reflectors 510 and 511. Then, the IDT 502 transforms the energy of the standing wave to an electric signal, so that an output potential is generated at the output pad 521. A transform characteristic of transforming an electric signal to SAW by

each of the IDTs 501 to 503 has a frequency characteristic, and thus the SAW filter 500 has a band-pass characteristic.

[0007]

The SAW filter 500 shown in Fig. 15 is a longitudinally coupled resonator SAW filter, in which the IDTs 501 and 503 for input and the IDT 502 for output are acoustically cascaded in an acoustic track sandwiched by the reflectors 510 and 511. Other than the longitudinally coupled resonator SAW filter, a transversely coupled resonator SAW filter, a transversal SAW filter, a ladder SAW filter, and a lattice SAW filter may be used.

[0008]

In any type of SAW filters, a conductive thin-film pattern serving as IDTs and wiring traces is disposed on a piezoelectric substrate, and a band-pass characteristic is obtained by using a frequency characteristic of an electric signal to SAW transform function of the IDTs.

[0009]

[Patent Document 1]

Japanese Unexamined Patent Application Publication No. 5-167387 (Publication Date: July 2, 1993)

[0010]

[Patent Document 2]

Japanese Unexamined Patent Application Publication No. 5-235684 (Publication Date: September 10, 1993)

[0011]

[Patent Document 3]

Japanese Unexamined Patent Application Publication No. 7-30362 (Publication Date: January 31, 1995)

[0012]

[Patent Document 4]

Japanese Unexamined Patent Application Publication No. 2000-49567 (Publication Date: February 18, 2000)

[0013]

[Patent Document 5]

Japanese Unexamined Patent Application Publication No. 2000-138553 (Publication Date: May 16, 2000)

[0014]

[Problems to be Solved by the Invention]

In the known SAW filters, a filter characteristic may be deteriorated due to parasitic capacitance generated between wiring traces on a piezoelectric substrate. Parasitic capacitance generated between a wiring trace receiving an input signal and a wiring trace generating an output signal serves as a current bypass from an input-signal terminal to an output-signal terminal. Therefore, the parasitic capacitance degrades the suppression level for signals of frequencies outside a pass band.

[0015]

In particular, a SAW filter having many IDTs requires

many wiring traces for connecting the IDTs. Further, the area to be covered increases, parasitic capacitance is more likely to be generated, and the size of the filter also increases.

[0016]

In a SAW filter having a balance-to-unbalance transformer function, in which any one of input and output is an unbalanced signal and the other is a balanced signal, parasitic capacitance between a wiring trace receiving an unbalanced signal and a wiring trace receiving a balanced signal serves as a current path for bringing unbalanced signals of same phase and same amplitude to two balanced signals which normally have to have opposite phases and same amplitude. Therefore, a common-mode signal in each balanced signal increases, so that the degree of balance is deteriorated.

[0017]

As described above, parasitic capacitance between wiring traces, in particular, parasitic capacitance between wiring traces having different potentials, has a bad effect on the characteristic of a SAW filter. Specifically, when a piezoelectric substrate comprises a material having relative permittivity of more than 20, for example, $LiTaO_3$, $LiNbO_3$, or $Li_2B_4O_7$, parasitic capacitance becomes very large, and thus the bad effect becomes significant. Also, larger current

flows through the parasitic capacitance as the frequency is higher. Therefore, a SAW filter having a higher-frequency pass band receives worse effect.

[0018]

It is an object of the present invention to provide a SAW filter in which parasitic capacitance between wiring traces is small and the signal suppression level outside the pass band is high. Also, it is another object of the present invention to provide a SAW filter having an unbalance-to-balance transformer function in which a balanced signal has a preferable degree of balance.

[0019]

[Means for Solving the Problems]

In order to solve the above-described problems, a SAW filter of the present invention includes at least a piezoelectric substrate; an insulating pattern disposed on the piezoelectric substrate and having permittivity lower than that of the piezoelectric substrate; and a conductor pattern disposed on at least one of the piezoelectric substrate and the insulating pattern. Part of the conductor pattern serves as IDTs and another part thereof serves as wiring traces. At a portion where wiring traces having different potentials face each other in a plan view, at least part of at least one of the wiring traces is disposed on the insulating pattern.

[0020]

With this configuration, when part of the conductor pattern is disposed on the insulating pattern, the part on the insulating pattern is not directly in contact with the piezoelectric substrate having a high permittivity and is held on the piezoelectric substrate through the insulating pattern having a lower permittivity than that of the piezoelectric substrate. Accordingly, parasitic capacitance between that part and another part of the conductor pattern can be reduced. The parasitic capacitance increases as the permittivity of the piezoelectric substrate is higher.

[0021]

For example, when two conductor traces having a width of 20 μm are arranged in parallel with an interval of 20 μm on a $LiTaO_3$ substrate in a plan view, parasitic capacitance between the two conductor traces can be reduced to about 1/2, compared to a case where no insulating pattern is provided, by disposing one of the conductor traces on the insulating (resin) pattern having relative permittivity of 2 and thickness of 1 μm. Further, parasitic capacitance between the two conductor traces can be reduced to about 1/3, compared to a case where no insulating pattern is provided, by disposing both conductor traces on the insulating (resin) pattern having relative permittivity of 2 and thickness of 1 μm.

[0022]

Further, in the above-described configuration, at a portion where wiring traces having different potentials face each other in a plan view, where parasitic capacitance is likely to be generated, at least part of at least one of the wiring traces is disposed on the insulating pattern. Accordingly, the parasitic capacitance can be effectively reduced.

[0023]

With this configuration, deterioration in transmission characteristics, for example, increase in insertion loss in the pass band and decrease in suppression level (attenuation) outside the pass band (particularly, in the high-frequency side) caused by the parasitic capacitance, can be prevented. Accordingly, the transmission characteristics can be improved.

[0024]

In the above-described SAW filter, the conductor pattern may include a first conductor pattern disposed on the piezoelectric substrate, part thereof serving as the IDTs; and a second conductor pattern which is in conduction with the first conductor pattern, part thereof being disposed on the insulating pattern.

[0025]

In order to solve the above-described problems, another

SAW filter of the present invention includes a piezoelectric substrate; a first conductor pattern disposed on the piezoelectric substrate, part thereof serving as IDTs and at least another part thereof serving as a first wiring pattern; an insulating pattern disposed on the piezoelectric substrate and on the first wiring pattern; and a second conductor pattern disposed on the piezoelectric substrate and on the insulating pattern and being in conduction with the first conductor pattern, at least part thereof serving as a second wiring pattern. At a portion where wiring traces having different potentials face each other in a plan view in the first and second wiring patterns, at least part of at least one of the wiring traces is disposed on the insulating pattern. The first wiring pattern is crossed with the second wiring pattern in at least one point, with the insulating pattern disposed therebetween.

[0026]

With this configuration, the first wiring pattern is crossed with the second wiring pattern in at least one point, with the insulating pattern disposed therebetween. Herein, the first conductor pattern serves as a lower-layer first wiring pattern, the insulating pattern having smaller permittivity than that of the piezoelectric substrate serves as an interlayer insulating film, and the second conductor pattern serves as an upper-layer second wiring pattern. By

three-dimensionally crossing wiring traces of these patterns so as to lay out them on a single plane, space for the wiring traces (plane area in the thickness direction of the piezoelectric substrate) can be saved, and thus the SAW filter can be miniaturized.

[0027]

Also, in the above-described configuration, at a portion where wiring traces having different potentials face each other in a plan view in the first and second wiring patterns, at least part of at least one of the wiring traces is disposed on the insulating pattern. Accordingly, parasitic capacitance can be reduced more effectively as described above.

[0028]

With this configuration, deterioration in transmission characteristics, for example, increase in insertion loss in the pass band and decrease in suppression level (attenuation) outside the pass band (particularly, in the high-frequency side) caused by the parasitic capacitance, can be prevented. Accordingly, the transmission characteristics can be improved and the SAW filter can be miniaturized.

[0029]

Preferably, in the SAW filter, one of the wiring traces having different potentials receives an input signal and the

other wiring trace receives an output signal.

[0030]

In this configuration, when parasitic capacitance between the wiring trace for receiving an input signal and the wiring trace for receiving an output signal is reduced, current flowing from an input signal terminal to an output signal terminal through the parasitic capacitance is reduced. Accordingly, the signal suppression level outside the pass band of the SAW filter can be increased.

[0031]

Preferably, in the SAW filter, the relative permittivity of the insulating pattern is less than 4. With this configuration, by increasing the difference in relative permittivity of the insulating pattern and the piezoelectric substrate, the parasitic capacitance can be reduced more efficiently, and thus the transmission characteristic can be effectively improved.

[0032]

Preferably, in the SAW filter, the insulating pattern comprises resin. With this configuration, the relative permittivity of the insulating pattern can be reduced to about 2, and the difference in relative permittivity of the insulating pattern and the piezoelectric substrate can be increased. Accordingly, the parasitic capacitance can be reduced more efficiently, and thus the transmission

characteristic can be effectively improved.

[0033]

The insulating pattern can be easily formed, for example, by easily forming a resin layer on the piezoelectric substrate by spin-coating or spraying a photosensitive liquid resin or bonding a resin sheet, and then by performing patterning using photolithography. Alternatively, the insulating pattern can be easily formed by using screen printing or the like.

[0034]

By using resin, the insulating pattern can be easily formed. Further, by using resin, an insulating pattern having a thickness of about 1 μm or more can be formed relatively easily.

[0035]

The following problems occur when an insulating pattern is formed by using a ceramic material. In order to form a thin-film pattern (insulating pattern) by using a ceramic material, a lift-off method or etching may be adopted.

[0036]

When a thin-film pattern comprising a ceramic material is formed by a lift-off method, a ceramic film must be formed by depositing particles substantially vertically to a deposition surface. However, the melting point of a ceramic material is generally high, and thus vacuum evaporation,

which is a typical method for depositing particles substantially vertically to a deposition surface, is not preferable. Therefore, there is no other choice but to use a special high-cost deposition method, such as sputtering deposition using a collimator.

[0037]

When a thin-film pattern comprising a ceramic material is formed by etching, etching of the ceramic material must be performed while protecting the surface of the piezoelectric substrate serving as a path of SAW against damage, but this is very difficult. Actually, when etching of a ceramic material is performed, the surface of the piezoelectric substrate is damaged, and thus the characteristic of the SAW filter is more or less deteriorated.

[0038]

As described above, it is difficult to form a thin-film pattern (insulating pattern) comprising a ceramic material on a piezoelectric substrate at low cost. Even if a thin-film pattern (insulating pattern) comprising a ceramic material can be formed on a piezoelectric substrate, the thickness thereof is several hundreds of nm at the maximum. Also, the relative permittivity of a ceramic material is usually high of 4 or more. Therefore, it is difficult to reduce parasitic capacitance between conductor traces, in

particular, between conductor traces at a crossing portion.

[0039]

In the above-described configuration, however, the insulating pattern comprises resin. The interlayer insulating film has a low relative permittivity of about 2, and the thickness thereof is about 1 μm or more. With this configuration, parasitic capacitance between conductor traces at a crossing portion does not have bad effects on the characteristic of the SAW filter.

[0040]

In the SAW filter, the relative permittivity of the piezoelectric substrate may be 20 or more. Also, the piezoelectric substrate may comprise any of $LiTaO_3$, $LiNbO_3$, and $Li_2B_4O_7$. With this configuration, the difference in the relative permittivity of the insulating pattern and the piezoelectric substrate comprising any of $LiTaO_3$, $LiNbO_3$, and $Li_2B_4O_7$, having a relative permittivity of 20 or more, can be increased. Accordingly, the parasitic capacitance can be reduced more efficiently and the transmission characteristic can be effectively improved.

[0041]

In the SAW filter, the center frequency in the pass band may be 500 MHz or more. Alternatively, the center frequency in the pass band may be 1 GHz or more.

[0042]

In the above-described configuration, as the center frequency in the used pass band is higher, current flowing through parasitic capacitance becomes larger. In particular, when the center frequency in the pass band is 500 MHz or more, especially 1 GHz or more, current flowing through parasitic capacitance becomes large, and its effect becomes significant. Therefore, by using the above-described configuration in a SAW filter having the center frequency in the pass band, parasitic capacitance can be reduced and current flowing through the parasitic capacitance can be significantly reduced, and thus a substantial effect can be obtained.

[0043]

Preferably, in the SAW filter, the thickness of the insulating pattern is 0.5 μm or more. By setting the thickness of the insulating pattern to 0.5 μm or more, parasitic capacitance can be reduced more efficiently, and thus the transmission characteristic can be effectively improved.

[0044]

In the SAW filter, the IDTs may have a balance-to-unbalance transformer function.

[0045]

In the above-described configuration, the SAW filter has an unbalanced signal-to-balanced signal transformer

function, in which one of input and output signals is an unbalanced signal and the other signal is a balanced signal. In this SAW filter, when parasitic capacitance between a wiring trace for receiving an unbalanced signal and a wiring trace for receiving a balanced signal is reduced, current flowing from an unbalanced signal terminal to a balanced signal terminal through the parasitic capacitance reduces. Accordingly, common-mode signal suppression level increases and the degree of balance of the balanced signal is effectively improved.

[0046]

A communication apparatus of the present invention includes the above-described SAW filter. With this configuration, the communication apparatus has an excellent transmission characteristic and can be miniaturized.

[0047]

[Description of the Embodiments]

Hereinafter, embodiments of the present invention will be described with reference to Figs. 1 to 14.

[0048]

(First Embodiment)

As shown in Figs. 1 and 2, a surface acoustic wave (SAW) filter 200 according to a first embodiment includes a first conductor pattern 1, a resin pattern (insulating pattern) 2, and a second conductor pattern 3, which are

arranged on a piezoelectric substrate 100. In a direction vertical to the plane of Fig. 1, the piezoelectric substrate 100 is at the lowest position, and the first conductor pattern 1, the resin pattern 2, and the second conductor pattern 3 are disposed in this order. The piezoelectric substrate 100 comprises 38.5° rotated Y-cut X-propagation $LiTaO_3$ single crystal.

[0049]

The first conductor pattern 1 includes an aluminum thin-film which is 200 nm thick. The resin pattern 2 includes a polyimide film which is 1 μm thick. The second conductor pattern 3 includes two layers of conductive thin-films, in which the lower layer is a nichrome thin-film which is 200 nm thick and the upper layer is an aluminum thin-film which is 1000 nm thick.

[0050]

The first conductor pattern 1 serves as one-terminal-pair SAW resonators 11 and 12 and longitudinally coupled resonator SAW filters 13 and 14. The one-terminal-pair SAW resonator 11 includes a grating reflector 31, an interdigital transducer (IDT) 32, and a grating reflector 33, which are arranged along the SAW propagation direction. Likewise, the one-terminal-pair SAW resonator 12 includes a grating reflector 34, an IDT 35, and a grating reflector 36, which are arranged along the SAW propagation direction.

[0051]

The one-terminal-pair SAW resonators 11 and 12 have the same configuration. In specific design parameters thereof, each of the IDTs 32 and 35 and the grating reflectors 31, 33, 34, and 36 has a 1.06 μm pitch, and the metallization ratio thereof is 0.6. Also, the distance between the IDT and the grating reflector (distance between centers of adjoining electrode fingers) is 1.06 μm. The interdigital width of electrode fingers of the IDTs 32 and 35 is 74 μm. The number of electrode fingers in each of the IDTs 32 and 35 is 241, and the number of electrode fingers in each of the grating reflectors 31, 33, 34, and 36 is 30. In Fig. 1, a smaller number of electrode fingers are shown.

[0052]

The longitudinally coupled resonator SAW filter 13 includes a grating reflector 37, IDTs 38 to 40, and a grating reflector 41, which are arranged along the SAW propagation direction, and the longitudinally coupled resonator SAW filter 14 includes a grating reflector 42, IDTs 43 to 45, and a grating reflector 46, which are arranged along the SAW propagation direction.

[0053]

In design parameters of the longitudinally coupled resonator SAW filter 13, each of the grating reflectors 37 and 41 has a 1.09 μm pitch, and the metallization ratio

thereof is 0.57. Also, each of the IDTs 38 to 40 has a 1.08 μm pitch, and the metallization ratio thereof is 0.72.

[0054]

In each of the IDTs 38 to 40, however, three electrode fingers at the edge facing an adjoining IDT has a 0.96 μm pitch, and the metallization ratio thereof is 0.68. The distance between the IDT and the grating reflector (distance between centers of adjoining electrode fingers) is 1.02 μm. The distance between adjoining IDTs (distance between centers of adjoining electrode fingers) is 0.96 μm. The interdigital width of electrode fingers of the IDTs 38 to 40 is 90 μm. The number of electrode fingers in each of the grating reflectors 37 and 41 is 90, the number of electrode fingers in each of the IDTs 38 and 40 is 21, and the number of electrode fingers in the IDT 39 is 39. Although a smaller number of electrode fingers are shown in Fig. 1, the polarity of each electrode finger facing an adjoining IDT or grating reflector is precisely illustrated.

[0055]

In design parameters of the longitudinally coupled resonator SAW filter 14, each of the grating reflectors 42 and 46 has a 1.09 μm pitch, and the metallization ratio thereof is 0.57. Also, each of the IDTs 43 to 45 has a 1.08 μm pitch, and the metallization ratio thereof is 0.72.

[0056]

In each of the IDTs 43 to 45, however, three electrode fingers at the edge facing an adjoining IDT has a 0.96 μm pitch, and the metallization ratio thereof is 0.68. The distance between the IDT and the grating reflector (distance between centers of adjoining electrode fingers) is 1.02 μm. The distance between adjoining IDTs (distance between centers of adjoining electrode fingers) is 0.96 μm. The interdigital width of electrode fingers of the IDTs 43 to 45 is 90 μm. The number of electrode fingers in each of the grating reflectors 42 and 46 is 60, the number of electrode fingers in each of the IDTs 43 and 45 is 21, and the number of electrode fingers in the IDT 44 is 39. Although a smaller number of electrode fingers are shown in Fig. 1, the polarity of each electrode finger facing an adjoining IDT or grating reflector is precisely illustrated.

[0057]

In the IDTs 43 and 45, portions facing the IDT 44 are weighted in series. That is, in each of the IDTs 43 and 45, the length of two electrode fingers adjoining the IDT 44 is set to 1/2, a dummy electrode finger is provided at each of two electrode-finger lacking portions, and the two dummy electrode fingers are connected.

[0058]

The longitudinally coupled resonator SAW filters 13 and 14 have almost the same design. However, the polarity of

the IDTs 38 and 40 is opposite to that of the IDTs 43 and 45. Therefore, when receiving the same input signal, the longitudinally coupled resonator SAW filters 13 and 14 generate signals of almost the same amplitude and opposite phases.

[0059]

The second conductor pattern 3 serves as an input pad 15, a first output pad 16, a second output pad 17, ground pads 18 to 22, and wiring traces 51 to 63.

[0060]

The wiring trace 51 allows the input pad 15 and the IDT 39 to be electrically continuous. The wiring trace 52 allows the input pad 15 and the IDT 44 to be electrically continuous. The wiring trace 53 allows the ground pad 18 and the IDTs 40 and 43 to be electrically continuous.

[0061]

The wiring trace 54 allows the ground pad 19 and the IDT 38 to be electrically continuous. The wiring trace 55 allows the ground pad 20 and the IDT 45 to be electrically continuous. The wiring trace 56 allows the ground pad 21 and the IDT 39 to be electrically continuous. The wiring trace 57 allows the ground pad 22 and the IDT 44 to be electrically continuous.

[0062]

The wiring trace 58 allows the IDTs 38 and 32 to be

electrically continuous. The wiring trace 59 allows the IDTs 40 and 32 to be electrically continuous. The wiring trace 60 allows the IDTs 43 and 35 to be electrically continuous. The wiring trace 61 allows the IDTs 45 and 35 to be electrically continuous.

[0063]

The wiring trace 62 allows the IDT 32 and the first output pad 16 to be electrically continuous, and the wiring trace 63 allows the IDT 35 and the second output pad 17 to be electrically continuous.

[0064]

Herein, parts of the wiring traces 58 to 61 are disposed on the resin pattern 2, and at those parts, the piezoelectric substrate 100 and the wiring traces 58 to 61 are not directly in contact with each other. That is, they are separated from each other.

[0065]

The parts of the wiring traces 58 and 59 on the resin pattern 2, and the wiring trace 56 and the ground pad 21 serve as conductor traces having different potentials and facing each other in a plan view. This is the same for the wiring traces 60 and 61, and the wiring trace 57 and the ground pad 22.

[0066]

A method for manufacturing the SAW filter 200 is not

specified. For example, the first conductor pattern 1 may be formed on the piezoelectric substrate 100 by vacuum deposition and etching by using a photoresist pattern as a mask, then the resin pattern 2 may be formed, and then the second conductor pattern 3 may be formed by vacuum deposition and a lift-off method.

[0067]

A method for forming the resin pattern 2 is not specified either. For example, monomers to be polymerized so as to generate polyimide when exposed to ultraviolet rays are dispersed in a solvent. Then, the liquid is applied by spin coating, the solvent is volatilized by baking it so as to reduce its flowability, and then ultraviolet rays are radiated thereto through a photo mask for shielding part except the part to be the resin pattern 2. Accordingly, polyimide can be generated at the part for serving as the resin pattern 2. Then, a development process is performed by using a chemical solution for removing the remaining monomers, so that the resin pattern 2 comprising polyimide can be formed.

[0068]

Next, the operation of the SAW filter 200 will be described. When an input signal is applied to the input pad 15, the input signal is applied to the IDT 39 of the longitudinally coupled resonator SAW filter 13, and an

output signal is generated in the IDTs 38 and 40. The generated output signal is transmitted to the first output pad 16 through the one-terminal-pair SAW resonator 11.

[0069]

At the same time, when the input signal is applied to the input pad 15, the input signal is applied to the IDT 44 of the longitudinally coupled resonator SAW filter 14, and an output signal is generated in the IDTs 43 and 45. The generated output signal is transmitted to the second output pad 17 through the one-terminal-pair SAW resonator 12.

[0070]

The output signal generated by the longitudinally coupled resonator SAW filter 13 and the output signal generated by the longitudinally coupled resonator SAW filter 14 have almost the same amplitude and opposite phases. Therefore, the SAW filter 200 has an unbalance-to-balance transformer function, in which a balanced signal can be generated in each of the first and second output pads 16 and 17 by applying an unbalanced signal to the input pad 15.

[0071]

The band-pass characteristic of the SAW filter 200 can be almost achieved by the longitudinally coupled resonator SAW filters 13 and 14. Each of the one-terminal-pair SAW resonators 11 and 12 is designed so as to have an antiresonance frequency in a cut-off region in the high-

frequency side of the SAW filter 200, and functions so as to improve signal suppression in the cut-off region in the high-frequency side of the SAW filter 200.

[0072]

In each of the longitudinally coupled resonator SAW filters 13 and 14 itself, output impedance may be capacitively shifted in the high-frequency side in the pass band, and thus impedance matching may be deteriorated. However, each of the one-terminal-pair SAW resonators 11 and 12 is designed so as to have inductive impedance in its frequency region, and functions so as to improve impedance matching in the frequency region.

[0073]

Herein, parts of the wiring traces 58 to 61, to which outputs of the longitudinally coupled resonator SAW filters 13 and 14 are applied, are disposed on the resin pattern 2. At those parts, the piezoelectric substrate 100 is not directly in contact with the wiring traces 58 to 61.

[0074]

Accordingly, parasitic capacitance between input and output units of the longitudinally coupled resonator SAW filter 13 is smaller than a case where the resin pattern 2 is not provided. That is, smaller current flows from the input unit to the output unit of the longitudinally coupled resonator SAW filter 13 through the parasitic capacitance.

[0075]

Likewise, parasitic capacitance between input and output units of the longitudinally coupled resonator SAW filter 14 is smaller than a case where the resin pattern 2 is not provided. That is, smaller current flows from the input unit to the output unit of the longitudinally coupled resonator SAW filter 14 through the parasitic capacitance.

[0076]

By providing the resin pattern 2, smaller current flows from the input unit to the output unit of the longitudinally coupled resonator SAW filter 13 through the parasitic capacitance, and at the same time, smaller current flows from the input unit to the output unit of the longitudinally coupled resonator SAW filter 14 through the parasitic capacitance. Accordingly, signal suppression outside the pass band of the SAW filter 200 can be improved and also common-mode signal suppression can be improved, so that the degree of balance of a balanced signal can be increased.

[0077]

Another effect can be obtained by disposing parts of the wiring traces 58 to 61 on the resin pattern 2.

[0078]

Each of the one-terminal-pair SAW resonators 11 and 12 is designed so as to have inductive impedance in the high-frequency side of the pass band. Therefore, if the resin

pattern 2 is not provided, parallel resonance or the like occurs and large current flows between the one-terminal-pair SAW resonators 11 and 12 including inductive impedance and ground capacitance of the wiring traces 58 to 61 in the high-frequency side of the pass band, so that energy loss is caused by heat due to ohmic resistance. The energy loss caused by the heat increases insertion loss in the pass band.

[0079]

In the present invention, the ground capacitance of the wiring traces 58 to 61 decreases by disposing parts of the wiring traces 58 to 61 on the resin pattern 2. Therefore, the amount of current flowing between the one-terminal-pair SAW resonators 11 and 12 and the wiring traces 58 to 61 reduces, and thus insertion loss in the pass band can be reduced.

[0080]

In the SAW filter 200 of the first embodiment, only the wiring traces 58 to 61 are on the resin pattern 2. Alternatively, parts of all the wiring traces may be disposed on the resin pattern 2.

[0081]

However, grounded wiring traces are not preferably disposed on the resin pattern and the potential of the piezoelectric substrate 100 is stabled at the ground potential. Further, wiring traces, to which a high-

frequency signal is applied, having a different potential from that of the grounded wiring traces are preferably disposed on the resin pattern, so as to reduce parasitic capacitance between the wiring traces and other wiring traces. Accordingly, the degree of balance of a balanced signal can be effectively increased. The use of the resin pattern is also effective in other embodiments which will be described later.

[0082]

Figs. 3 and 4 show transmission characteristics of the SAW filter 200 and a SAW filter according to a comparative example. Also, Figs. 5 and 6 show the degree of balance in amplitude and phase of a balanced signal in each of the SAW filter 200 and the SAW filter of the comparative example. Fig. 7 shows common-mode suppression in the SAW filter 200 and the SAW filter of the comparative example. The SAW filter of the comparative example used in Figs. 3 to 7 has the same configuration as that of the SAW filter 200 except that the resin pattern 2 is not provided therein.

[0083]

As can be seen in Fig. 3, insertion loss in the pass band in the first embodiment is lower than that in the comparative example, especially in the high-frequency side. Also, as is clear from Fig. 4, insertion loss (signal suppression level) is higher in a high-frequency region of

3000 to 5000 MHz outside the pass band in the first embodiment, compared to the comparative example.

[0084]

As shown in Fig. 5, regarding the amplitude difference in a balanced signal in the pass band, no significant difference exists between the first embodiment and the comparative example. However, as is clear from Fig. 6, the phase difference in the balanced signal in the pass band is closer to 180° (opposite phase) and the phase is well balanced in the first embodiment, compared to the comparative example. Also, as shown in Fig. 7, common-mode in the pass band can be suppressed more effectively in the first embodiment than in the comparative example. Accordingly, as can be seen in Figs. 5 and 6, the degree of balance of the balanced signal is more preferable in the first embodiment than in the comparative example.

[0085]

(Second Embodiment)

Fig. 8 shows a SAW filter 300 according to a second embodiment. Fig. 9 is a cross-sectional view taken along the line Y-Y' in Fig. 8. In the SAW filter 300 shown in Fig. 8, parts denoted by the same reference numerals as in Fig. 1 have the same function as that in the SAW filter 200. The differences between the SAW filters 300 and 200 are the shape of the resin pattern 2 and the wiring traces.

Hereinafter, the different parts will be described.

[0086]

A wiring trace 301 is part of the second conductor pattern 3 and allows the input pad 15 and the IDT 39 to be electrically continuous. A wiring trace 302 is part of the second conductor pattern 3 and allows the input pad 15 and the IDT 44 to be electrically continuous.

[0087]

A wiring trace 303 is part of the second conductor pattern 3 and allows the IDTs 38 and 32 and the IDTs 40 and 32 to be electrically continuous. A wiring trace 304 is part of the second conductor pattern 3 and allows the IDTs 43 and 35 and the IDTs 45 and 35 to be electrically continuous.

[0088]

A wiring trace 305 is part of the second conductor pattern 3 and allows the IDT 32 and the first output pad 16 to be electrically continuous. A wiring trace 306 is part of the second conductor pattern 3 and allows the IDT 35 and the second output pad 17 to be electrically continuous.

[0089]

A wiring trace 307 is part of the first conductor pattern 1 and allows the IDT 38 and the ground pad 18, the IDT 39 and the ground pad 18, the IDT 40 and the ground pad 18, the IDT 43 and the ground pad 18, the IDT 44 and the

ground pad 18, and the IDT 45 and the ground pad 18 to be electrically continuous.

[0090]

The wiring trace 307 is three-dimensionally crossed with the wiring traces 301 to 304. At the crossing portions, the wiring trace 307 serves as a lower-layer wiring formed by the first conductor pattern 1, the resin pattern 2 serves as an interlayer insulating film, and the wiring traces 301 to 304 serve as an upper-layer wiring formed by the second conductor pattern 3. At the crossing portions, the wiring trace 307 and the wiring traces 301 to 304 sandwich the resin pattern 2 so as to be crossed with each other without being in conduction to each other. Part of the wiring trace 307 is covered by the second conductor pattern 3, but at the crossing portions of the wiring trace 307 and the wiring traces 301 to 304, the wiring trace 307 serves as a single-layer wiring trace formed by the first conductor pattern 1.

[0091]

Miniaturization of the SAW filter 300 can be achieved by three-dimensionally crossing the wiring traces. Also, the length of each wiring trace for transmitting a signal can be reduced, and thus insertion loss can be effectively reduced.

[0092]

Additionally, in the SAW filter 300, by providing the

resin pattern 2, short-circuit at crossing portions can be prevented. Also, parasitic capacitance between wiring traces of different potentials which face each other (particularly, close to each other) in the direction of the surface of the piezoelectric substrate 100, for example, between the wiring traces 303 and 307 and between the wiring traces 304 and 307, can be reduced. Accordingly, insertion loss in the pass band can be reduced and suppression level outside the pass band (particularly, in the high-frequency side) can be increased.

[0093]

(Third Embodiment)

Fig. 10 shows a SAW filter 400 according to a third embodiment. Fig. 11 is a cross-sectional view taken along the line Z-Z' in Fig. 10. The SAW filter 400 is a ladder band-pass filter including three one-terminal-pair SAW resonators 401 to 403 connected in a ladder pattern. The specific operating principles of the ladder filter are known, and thus they are not described here.

[0094]

All of the one-terminal-pair SAW resonators 401 to 403, wiring traces 404 to 409, an input pad 410, an output pad 411, and a ground pad 412 are part of the first conductor pattern 1 disposed on the piezoelectric substrate 100. The one-terminal-pair SAW resonators 401 to 403 are arranged so

that the SAW propagation directions thereof are substantially parallel to each other.

[0095]

Parts of the wiring traces 404 to 407 at the positions facing each other in a plan view are disposed on the resin pattern 2. A method for manufacturing the SAW filter 400 is not specified. For example, the resin pattern 2 is formed on the piezoelectric substrate 100, a conductive thin-film is formed on the entire surface by vacuum evaporation, and then the conductive thin-film is patterned by dry etching so as to form the first conductor pattern 1.

[0096]

In the SAW filter 400, the resin pattern 2 is provided between at least parts of the wiring traces 404 to 407 and the piezoelectric substrate 100 at the positions where the wiring traces 404 to 407 face each other in a plan view. With this configuration, parasitic capacitance between the wiring traces 404 and 405, between the wiring traces 406 and 408, and between the wiring traces 407 and 409 can be reduced. Accordingly, insertion loss in the pass band can be reduced and the suppression level outside the pass band (particularly, in the high-frequency side) can be increased.

[0097]

Figs. 12 and 13 show modifications of the third embodiment. In the modifications, another resin pattern 2

is provided under the wiring trace 406 or 408 at the position facing the resin pattern 2 under the wiring trace 404 in a plan view, and still another resin pattern 2 is provided under the wiring trace 407 or 409 at the position facing the resin pattern 2 under the wiring trace 405 in a plan view.

[0098]

In each of the modifications, parasitic capacitance between the wiring traces 404 and 405, between the wiring traces 406 and 408, and between the wiring traces 407 and 409 can be further reduced. Accordingly, insertion loss in the pass band can be further reduced and the suppression level outside the pass band (particularly, in the high-frequency side) can be further increased.

[0099]

The resin pattern 2 in each embodiment may comprise an epoxy resin (glass-epoxy) or acrylic resin instead of polyimide. Although resin is preferably used, any insulating material may be used. Therefore, an insulating pattern using a ceramic material may also be used. As the ceramic material, SiO_2, SiN, or Al_2O_3 may be used.

[0100]

Next, a communication apparatus 600 including the SAW filter of the present invention will be described with reference to Fig. 14. The receiver side (Rx side) for

performing reception of the communication apparatus 600 includes an antenna 601, a duplexer/RF Top filter 602, an amplifier 603, an Rx interstage filter 604, a mixer 605, a 1st IF filter 606, a mixer 607, a 2nd IF filter 608, a 1st+2nd local synthesizer 611, a temperature compensated crystal oscillator (TCXO) 612, a divider 613, and a local filter 614. Preferably, balanced signals are transmitted from the Rx interstage filter 604 to the mixer 605 so as to ensure balance, as shown by two lines in Fig. 14.

[0101]

The transmitter side (Tx side) for performing transmission of the communication apparatus 600 includes the antenna 601 and the duplexer/RF Top filter 602, which are shared with the Rx side, a Tx IF filter 621, a mixer 622, a Tx interstage filter 623, an amplifier 624, a coupler 625, an isolator 626, and an automatic power control (APC) 627.

[0102]

The SAW filters according to the above-described embodiments can be preferably used for the duplexer/RF Top filter 602, the Rx interstage filter 604, and the Tx interstage filter 623.

[0103]

The communication apparatus includes the SAW filter having a favorable transmission characteristic (wide pass band and large amount of attenuation outside the pass band).

Therefore, favorable transmission/reception functions can be obtained and the communication apparatus can be miniaturized.

[0104]

[Advantages]

As described above, the SAW filter of the present invention includes the insulating pattern disposed on the piezoelectric substrate and having permittivity lower than that of the piezoelectric substrate; and the conductor pattern disposed on at least one of the piezoelectric substrate and the insulating pattern. Part of the conductor pattern serves as IDTs and another part thereof serves as wiring traces, and at a portion where wiring traces having different potentials face each other in a plan view, at least part of at least one of the wiring traces is disposed on the insulating pattern.

[0105]

In this configuration, at least part of the conductor pattern is disposed on the insulating pattern, which has a permittivity lower than that of the piezoelectric substrate. Therefore, at that part, the insulating pattern is disposed between the piezoelectric substrate and the conductor pattern.

[0106]

With this configuration, parasitic capacitance between at least part of the conductor pattern and another part of

the conductor pattern can be reduced by providing the insulating pattern. Accordingly, transmission characteristics (insertion loss in the pass band, suppression level outside the pass band, etc.) depending on the parasitic capacitance can be effectively improved.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a plan view of a SAW filter according to a first embodiment of the present invention.

[Fig. 2]

Fig. 2 is a cross-sectional view taken along the line X-X' in Fig. 1.

[Fig. 3]

Fig. 3 is a graph showing transmission characteristics in the first embodiment and a comparative example.

[Fig. 4]

Fig. 4 is a graph showing the transmission characteristics in the first embodiment and the comparative example in a higher-frequency band.

[Fig. 5]

Fig. 5 is a graph showing the degree of balance in amplitude of a balanced signal in each of the first embodiment and the comparative example.

[Fig. 6]

Fig. 6 is a graph showing the degree of balance in

phase of the balanced signal in each of the first embodiment and the comparative example.

[Fig. 7]

Fig. 7 is a graph showing common-mode suppression in each of the first embodiment and the comparative example.

[Fig. 8]

Fig. 8 is a plan view of a SAW filter according to a second embodiment of the present invention.

[Fig. 9]

Fig. 9 is a cross-sectional view taken along the line Y-Y' in Fig. 8.

[Fig. 10]

Fig. 10 is a plan view of a SAW filter according to a third embodiment of the present invention.

[Fig. 11]

Fig. 11 is a cross-sectional view taken along the line Z-Z' in Fig. 10.

[Fig. 12]

Fig. 12 is a plan view of a SAW filter according to a modification of the third embodiment of the present invention.

[Fig. 13]

Fig. 13 is a plan view of a SAW filter according to another modification of the third embodiment of the present invention.

[Fig. 14]

Fig. 14 is a circuit block diagram of a communication apparatus of the present invention.

[Fig. 15]

Fig. 15 is a plan view of a known SAW filter.

[Reference Numerals]

2: resin pattern (insulating pattern)

38 to 41: IDT (wiring trace, conductor trace)

58 to 61: wiring trace (conductor trace)

100: piezoelectric substrate

JP Application No. 2003-046269

[Name of Document] ABSTRACT

[Abstract]

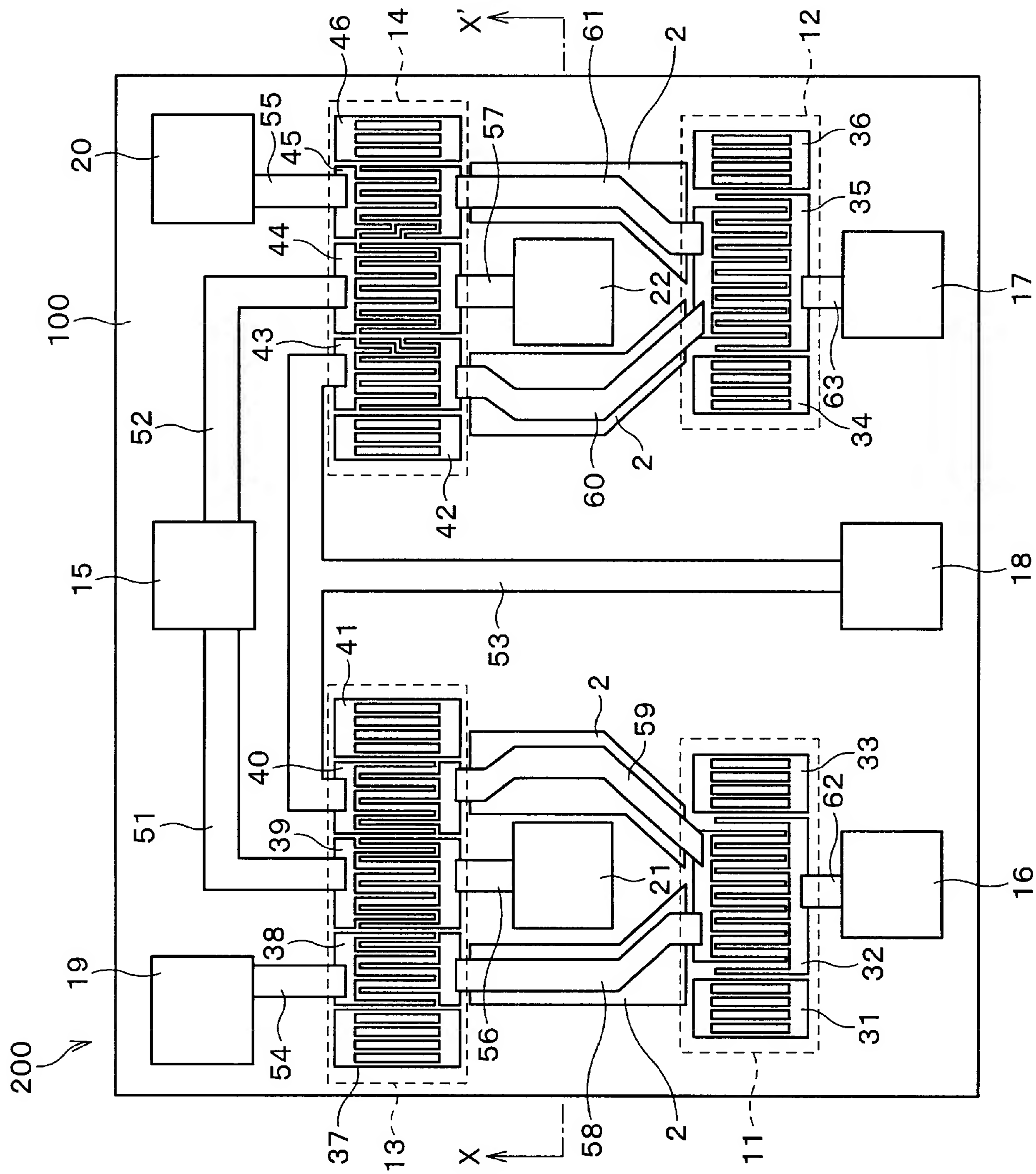
[Object] To provide a SAW filter having an unbalanced signal-to-balanced signal transformer function so as to obtain a balanced signal of a preferable degree of balance, in which parasitic capacitance between wiring traces is small and the signal suppression level outside the pass band is high, and to provide a communication apparatus including the same.

[Solving Means] On a piezoelectric substrate 100, an insulating pattern 2 having a permittivity lower than that of the piezoelectric substrate 100 is disposed. Wiring traces 38 to 41 and 58 to 61 are disposed on the piezoelectric substrate 100 and on the insulating pattern 2. The wiring traces 38 to 41 serve as an IDT 13. Parts of the wiring traces 58 to 61 having different potentials, at a portion where the wiring traces face each other in a plan view, are disposed on the insulating pattern 2.

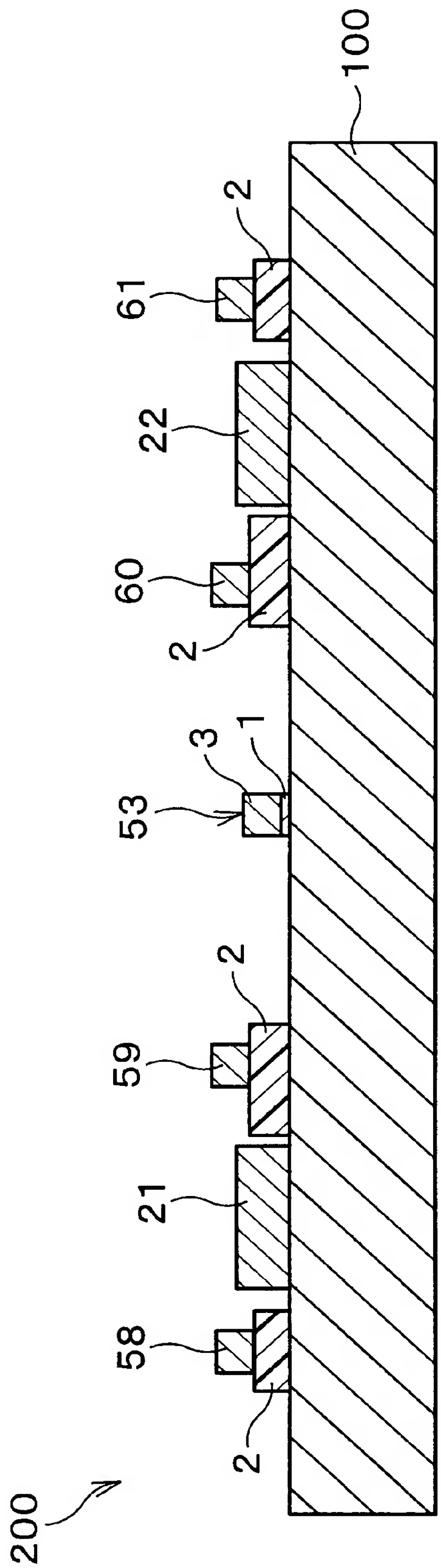
[Selected Figure] Fig. 1

【書類名】　図面　[Name of Document] DRAWINGS

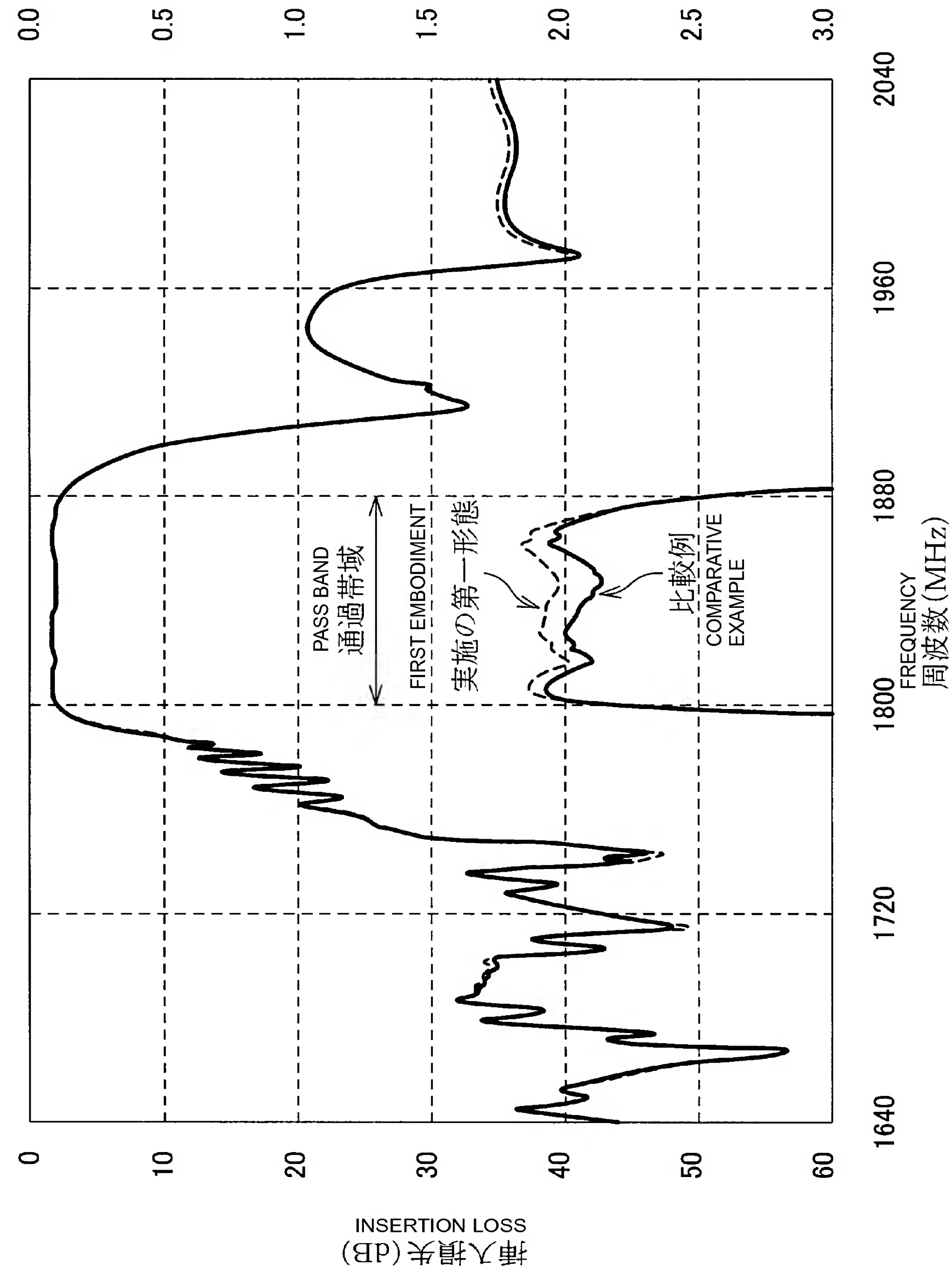
【図１】　[FIG. 1]



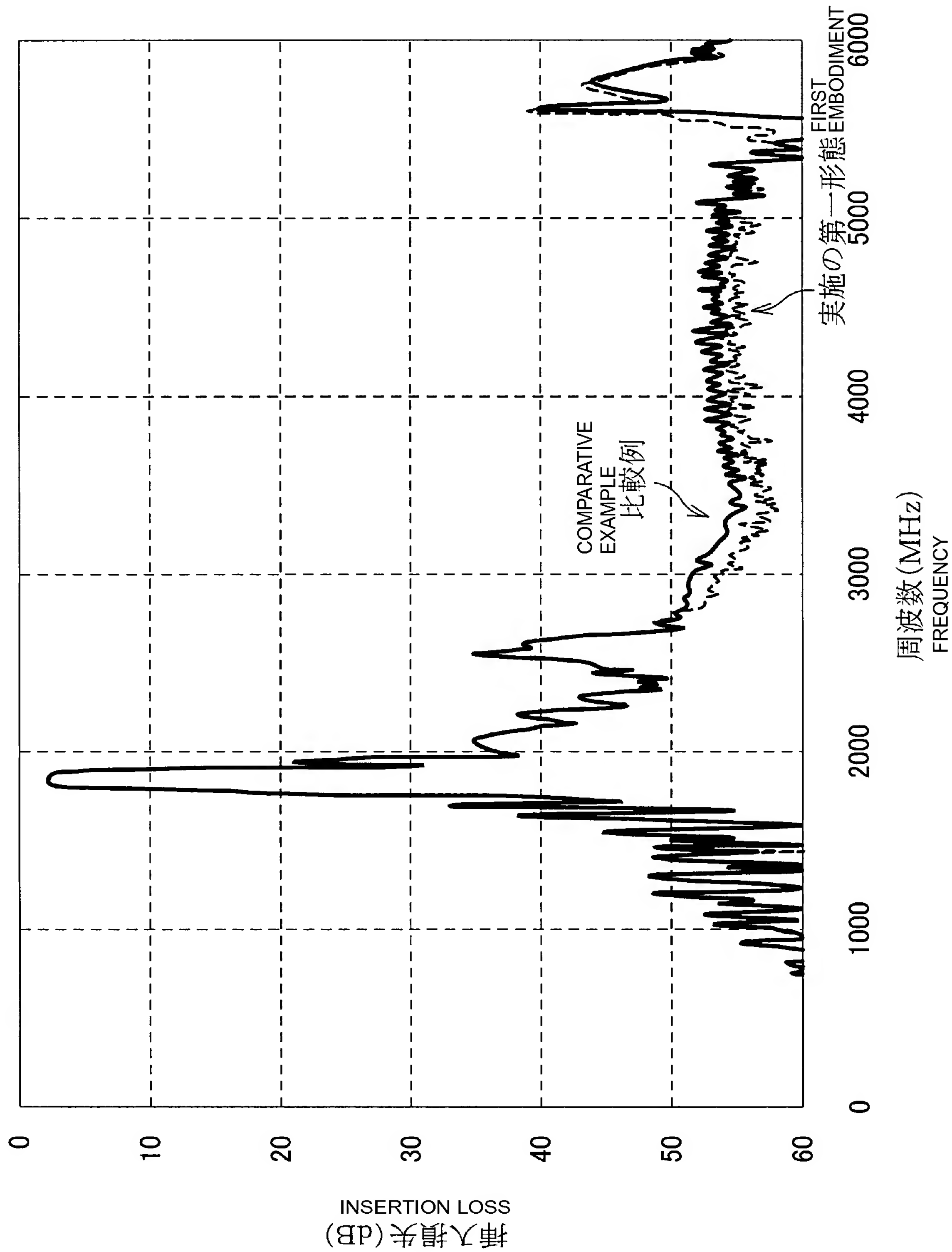
【図２】　[FIG. 2]



【図３】 [FIG. 3]

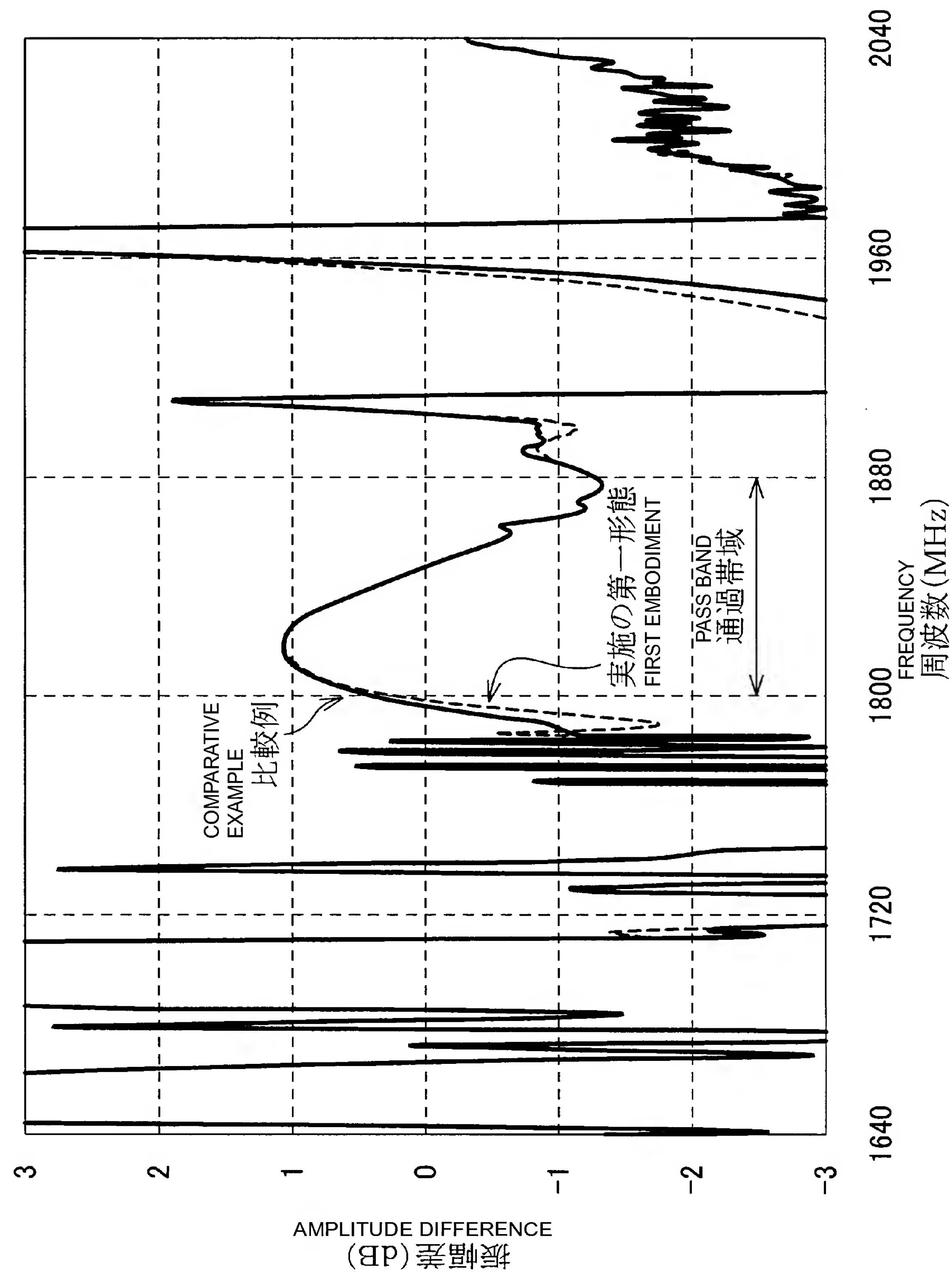

PASS BAND
通過帯域
FIRST EMBODIMENT
実施の第一形態
比較例
COMPARATIVE
EXAMPLE
FREQUENCY
周波数(MHz)
INSERTION LOSS
挿入損失(dB)
1640
1720
1800
1880
1960
2040
0
10
20
30
40
50
60
0.0
0.5
1.0
1.5
2.0
2.5
3.0

【図４】　[FIG. 4]

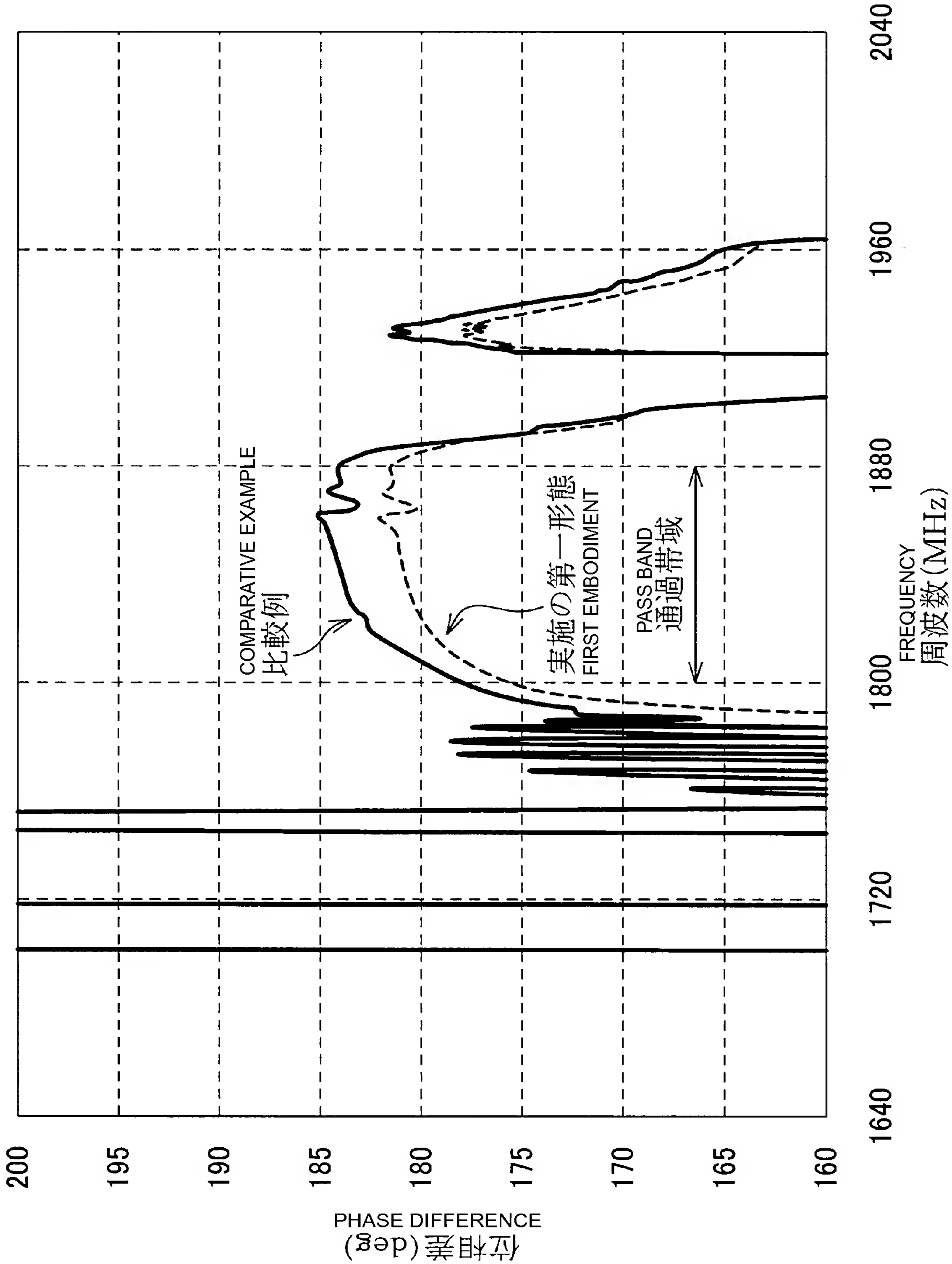


挿入損失(dB)
INSERTION LOSS
0
10
20
30
40
50
60
周波数(MHz)
FREQUENCY
0
1000
2000
3000
4000
5000
6000
COMPARATIVE
EXAMPLE
比較例
実施の第一形態
FIRST
EMBODIMENT

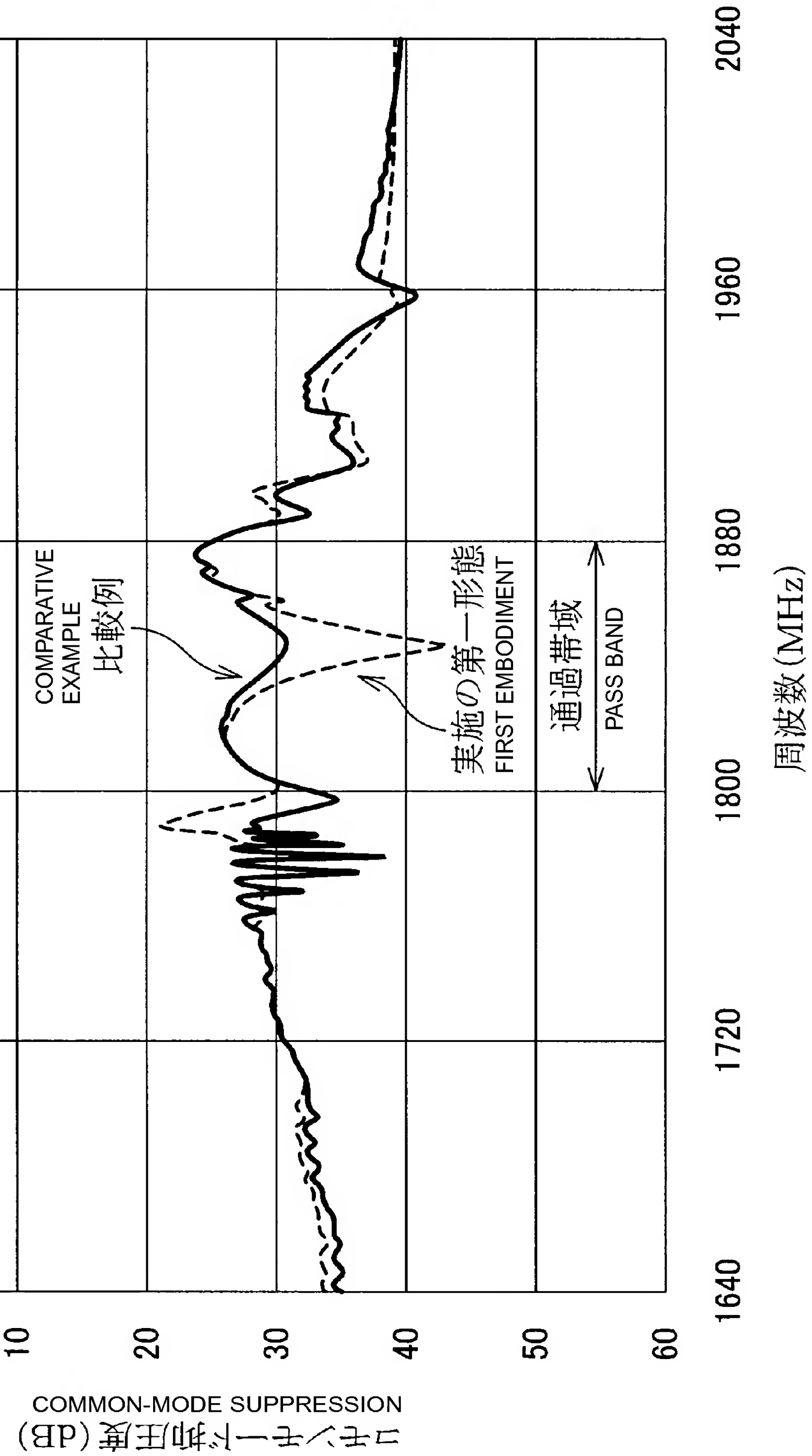
【図５】 [FIG. 5]


AMPLITUDE DIFFERENCE
振幅差(dB)
3
2
1
0
−1
−2
−3
FREQUENCY
周波数(MHz)
1640
1720
1800
1880
1960
2040
COMPARATIVE EXAMPLE
比較例
実施の第一形態
FIRST EMBODIMENT
PASS BAND
通過帯域

【図６】 [FIG. 6]

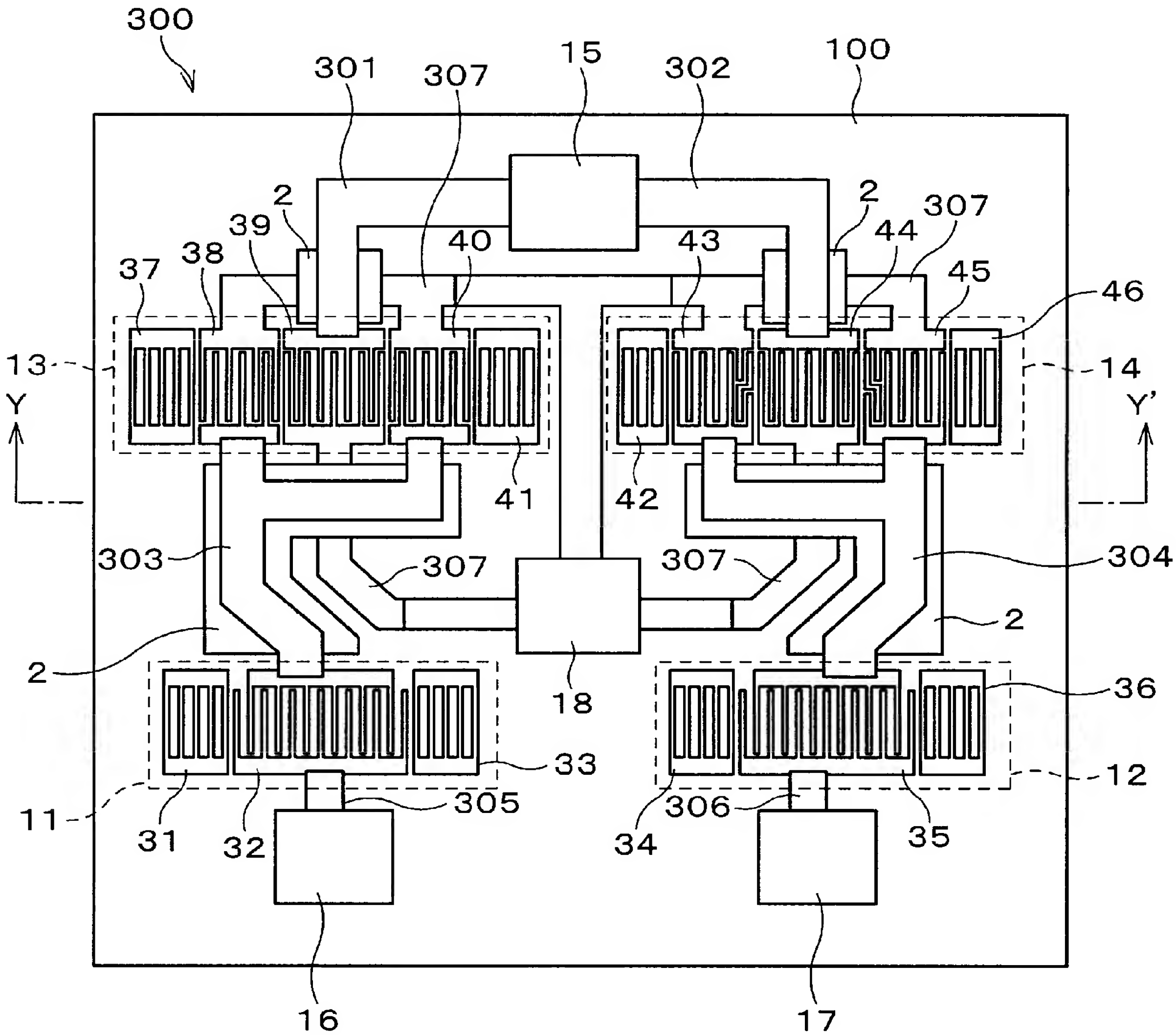

COMPARATIVE EXAMPLE
比較例
実施の第一形態
FIRST EMBODIMENT
PASS BAND
通過帯域
FREQUENCY
周波数 (MHz)
PHASE DIFFERENCE
位相差 (deg)
1640
1720
1800
1880
1960
2040
200
195
190
185
180
175
170
165
160

【図７】　[FIG. 7]

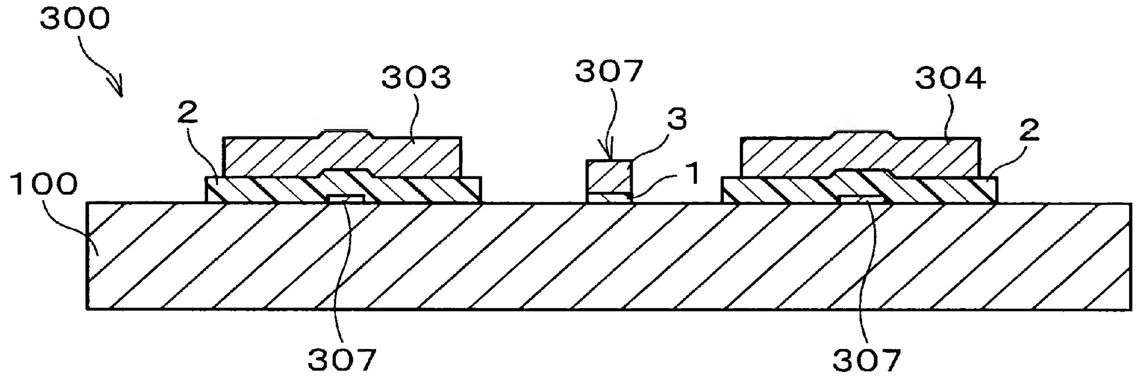


COMPARATIVE EXAMPLE
比較例
実施の第一形態
FIRST EMBODIMENT
通過帯域
PASS BAND
周波数（MHz）
FREQUENCY
1640
1720
1800
1880
1960
2040
0
10
20
30
40
50
60
コモンモード抑圧度（dB）
COMMON-MODE SUPPRESSION

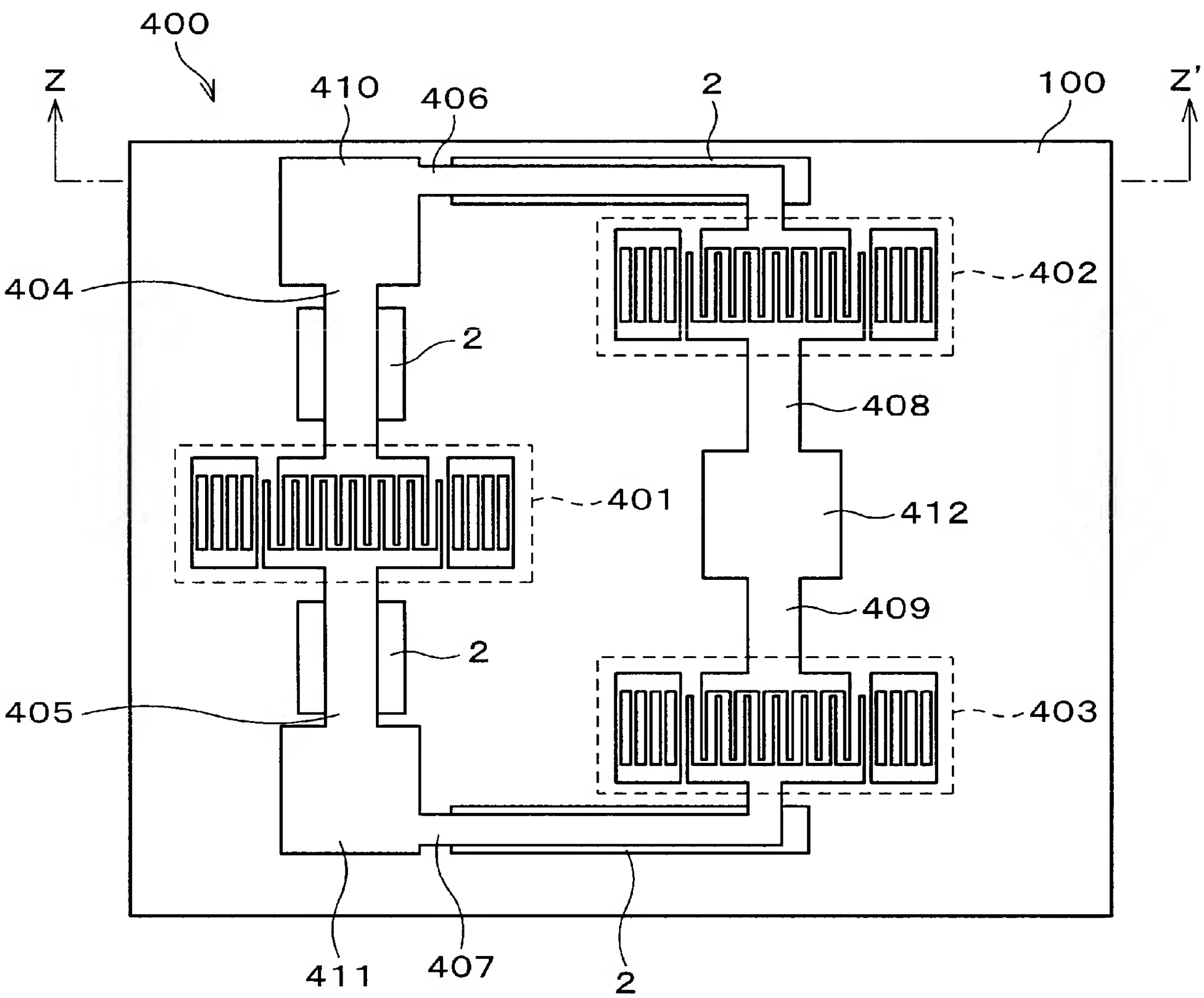
【図８】 [FIG. 8]


300
301
307
15
302
100
2
39
38
37
40
43
2
307
44
45
46
13
14
Y
Y'
41
42
303
307
307
304
2
2
18
36
33
12
11
31
32
305
34
306
35
16
17

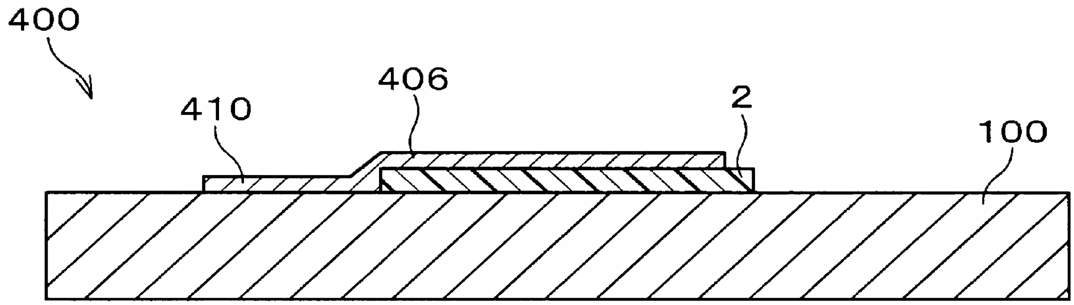
【図９】 [FIG. 9]



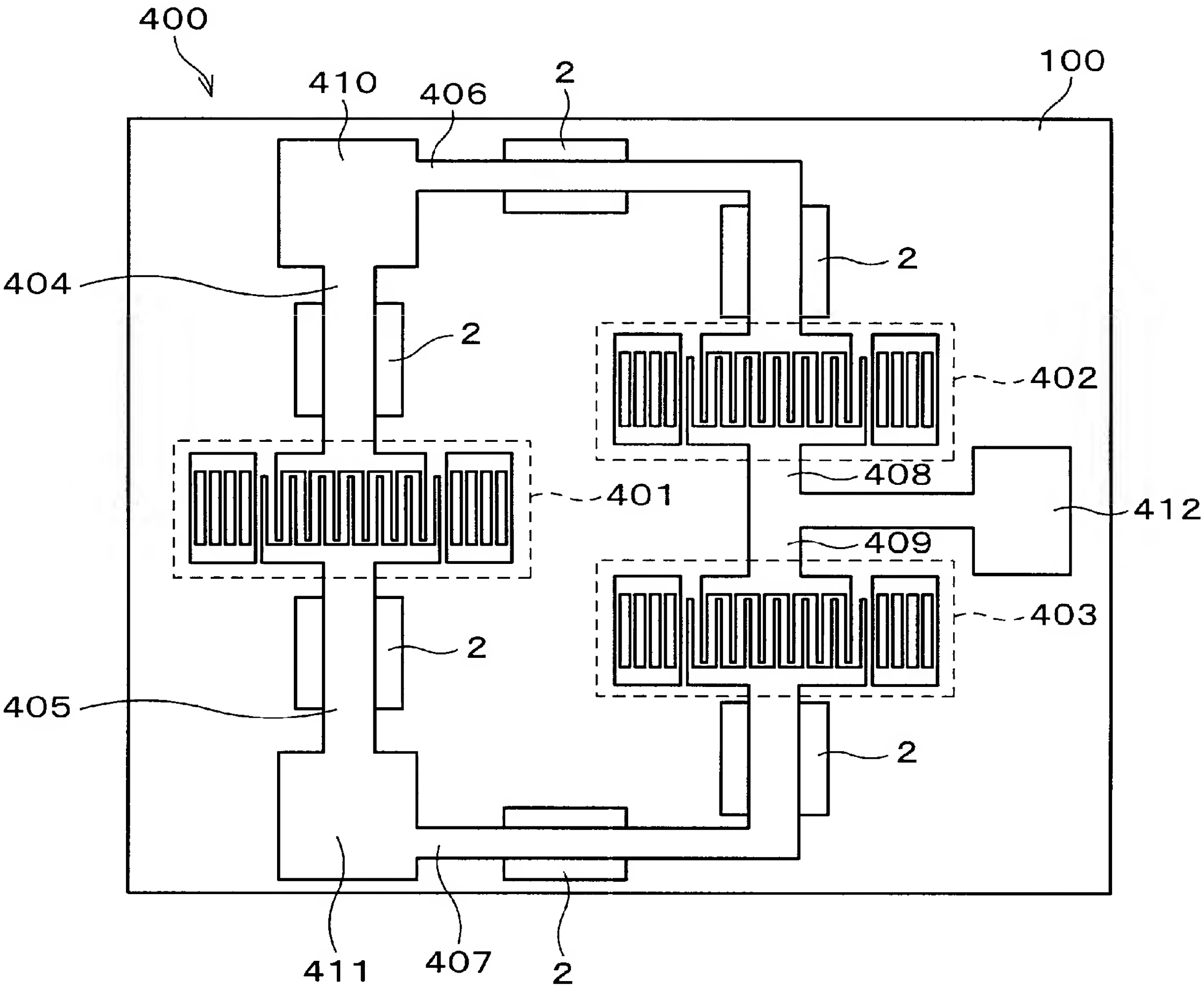
【図１０】 [FIG. 10]



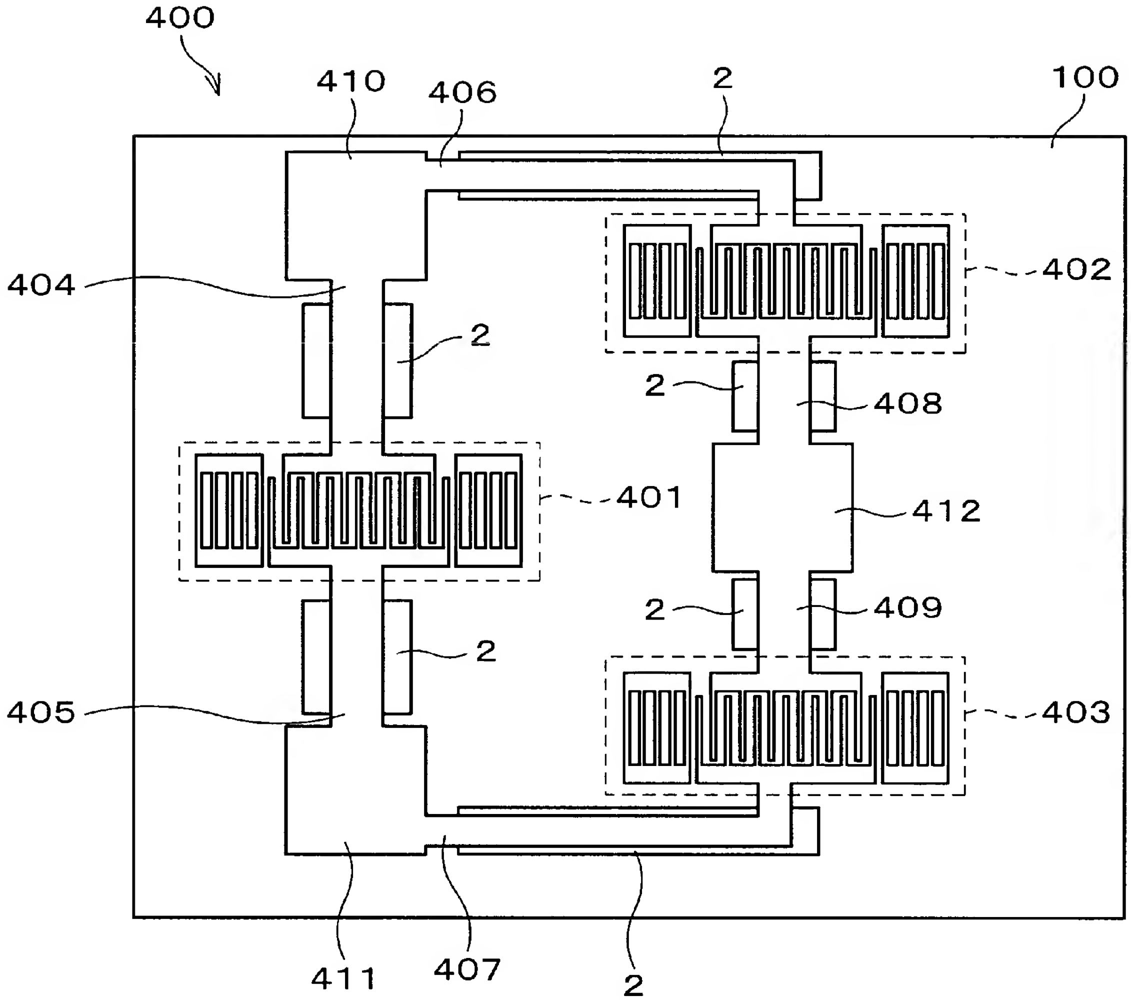
【図１１】 [FIG. 11]



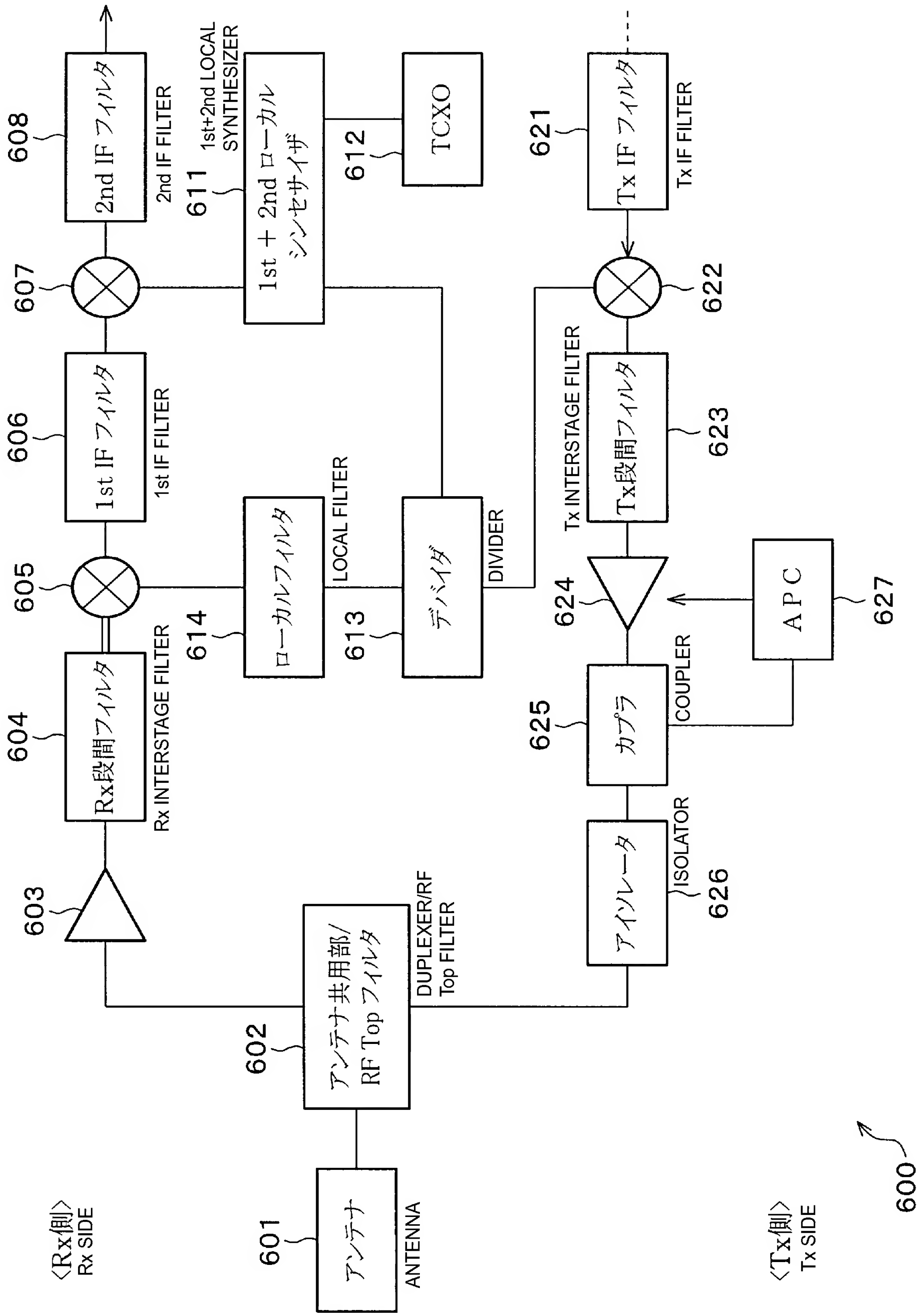
【図１２】 [FIG. 12]



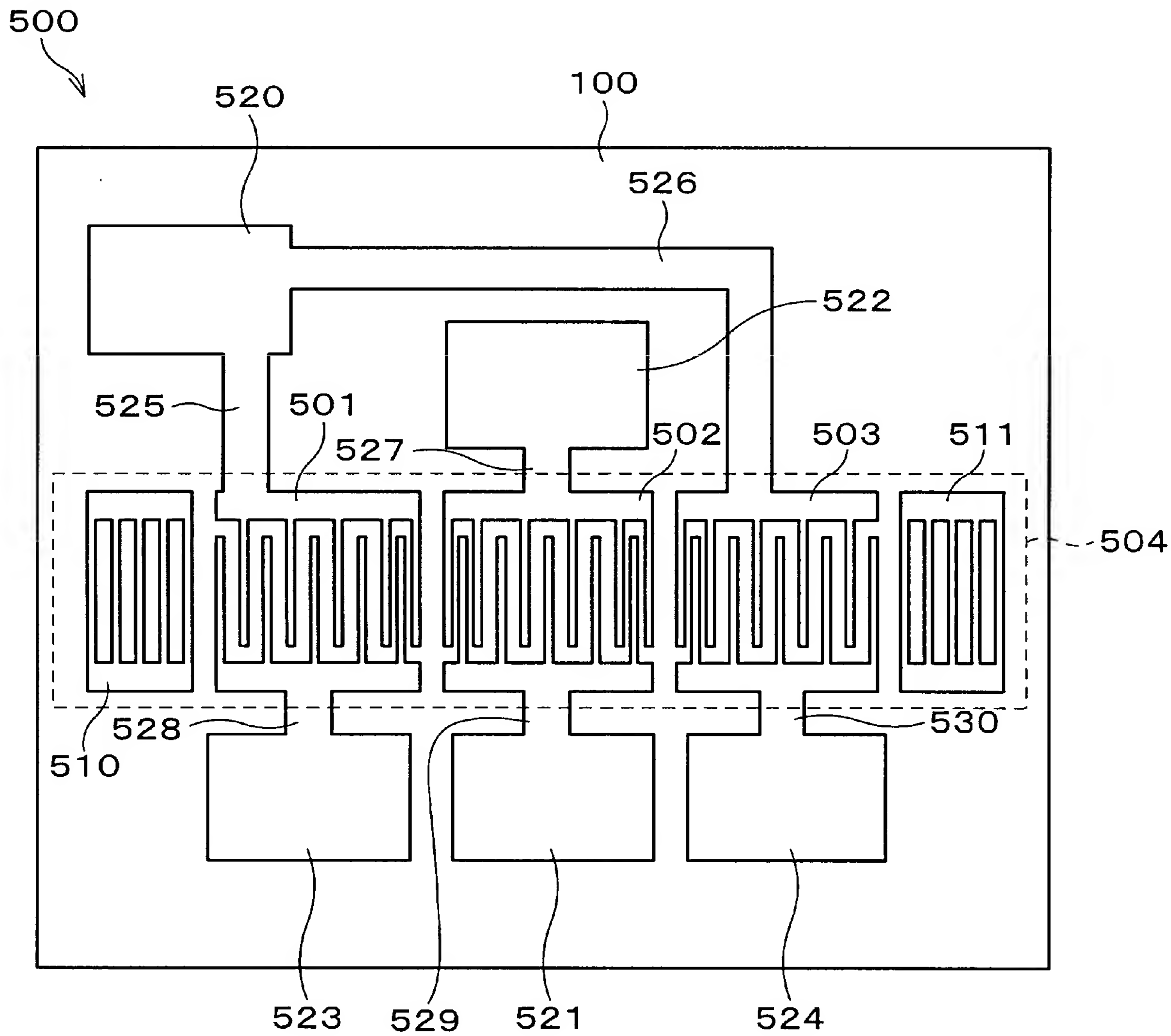
【図１３】 [FIG. 13]



【図１４】 [FIG. 14]


〈Rx側〉
Rx SIDE
〈Tx側〉
Tx SIDE
601
アンテナ
ANTENNA
602
アンテナ共用部/
RF Top フィルタ
DUPLEXER/RF
Top FILTER
603
604
Rx段間フィルタ
Rx INTERSTAGE FILTER
605
606
1st IF フィルタ
1st IF FILTER
607
608
2nd IF フィルタ
2nd IF FILTER
611
1st ＋ 2nd ローカル
シンセサイザ
1st+2nd LOCAL
SYNTHESIZER
612
TCXO
613
デバイダ
DIVIDER
614
ローカルフィルタ
LOCAL FILTER
621
Tx IF フィルタ
Tx IF FILTER
622
623
Tx段間フィルタ
Tx INTERSTAGE FILTER
624
625
カプラ
COUPLER
626
アイソレータ
ISOLATOR
627
A P C
600

【図１５】 [FIG. 15]


500
520
100
526
522
525
501
527
502
503
511
504
528
530
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523
529
521
524